§1. Study of Potential Confinement Mechanism via Plasma Visualization Technology

Mase, A., Kogi, Y., Ignatenko, M., Kudo, K. (KASTEC, Kyushu Univ.),
Yoshikawa, M., Nakahara, A., Itakura, A., Hojo, H., Cho, T. (PRC, Univ. Tsukuba),
Nagayama, Y.

In tandem mirrors, an electrostatic potential is created in order to improve axial confinement. The radial electric field due to this potential causes an $\boldsymbol{E}\times\boldsymbol{B}$ plasma rotation in the direction of the ion diamagnetic drift velocity. The verification of the effect is one of the most critical issues to understand the physics basis for recent confinement improvement. Understanding the mechanism of this effect requires the use of sophisticated diagnostic tools for measurement of plasma profiles and their fluctuations. Significant advances in microwave and millimeter wave technology have enabled the development of a new generation of imaging diagnostics as visualization tool of plasma parameters. This report describes the development of millimeter wave imaging diagnostics (a phase imaging interferometer) applied to the GAMMA 10 tandem mirror.

The details of the phase imaging interferometer was described in elsewhere.[1] The quadrature detection system provides the phase difference between two intermediate frequency (IF) signals obtained by mixing the transmitted signal (RF) and the local oscillator signal (LO). The phase difference is proportional to the line density of plasmas. In the last fiscal year, the quadrature phase detector is limited to 4, at least 4 plasma shots with good reproducibility are needed to obtain a full 2D profile. However, in FY2005, we have increased the number of phase detector to use all of the detector channels in one plasma shot.

The changes in the 2D line-density profiles for the case of high and low ECRH powers are shown in Fig. 1. The magnetic field strength is also shown in Fig. 1. Before the application of the ECRH power (t=164 ms), the electron density is distributed along the magnetic field lines. When the ECRH power is applied at t=180 ms, the plug potential is created near the position of z=961 cm where the magnetic field strength equals to 1 T. It is noted that the density profile in the core region decreases during the injection of the ECRH power. At the outside of the plug potential (z>961 cm), the plasma flow is disappeared due to the formation of the confining potential. When the ECRH power is high, the position is shifted. The position of the plug potential may be shifted for the case of high power ECRH. When the ECRH power is turned off at t=190 ms, the confining potential disappears, and a short burst appears in the line-density signal corresponding to the axial drain of the plasmas. The variation of the profile in the axial direction is caused by the change in the magnetic field. The resolution of the interferometer is estimated to be less than 1/200 fringe.

The imaging array antennas and intermediate frequency (IF) systems, in the frequency range of f=70 GHz and 1-4 GHz respectively, have been designed and fabricated by using microwave integrated circuit (MIC) technology to improve the spatial resolution and the signal to noise ratio of the imaging system.[2]

We have also performed the numerical study of microwave imaging reflectometry (MIR) for the GAMMA 10 plasma.[3] The main results are as follows. Depending on the cutoff curvature and spreading of reflected beam, the size of optics is the main limitation factor deteriorating MIR performance. Both conventional and imaging reflectometers can measure small amplitude and wave number fluctuations, however, only MIR system can measure density fluctuations with larger amplitude and wave number ($\Delta n/n_0$>0.04, $\Delta k/k_0$>0.5, where n_0 is the mean electron density, k_0 is the incident wave number, and Δ denotes those fluctuation components).

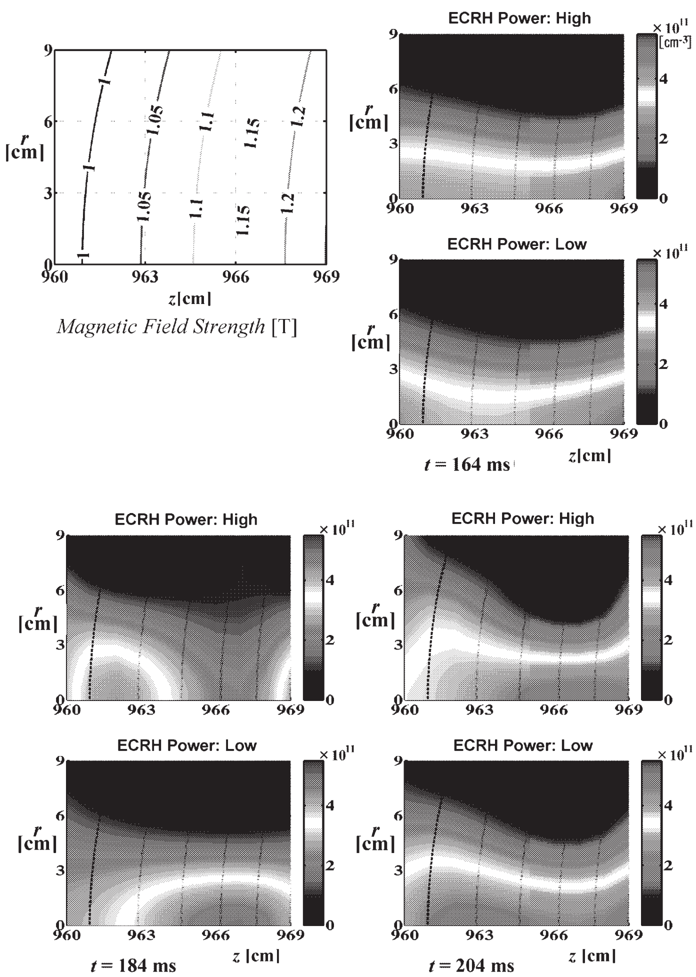

Fig.1. Time evolution of 2D line density profiles.

References
1) Watabe, K. et al., Rev. Sci. Instrum. 73, 2282 (2002).
2) Kogi, Y. et al., Proc. Joint 30th Int. Conf. on Infrared and Millimeter Waves and 13th Int. Conf. on Terahertz Electronics, Williamsburg (2005) pp. 604-605.
3) Ignatenko, M., Mase, A., Bruskin, L. G., Kogi, Y., and Hojo, H., to be published in Nucl. Fusion.